Study of the resonance region with pion electro-production

A recount of work done with Paul Stoler

Angela Biselli
Professor at Fairfield University

Fairfield University

Orsay, France, May 30, 2017

Physics motivation

CEBAF Program Advisory Committee Eight Cover Sheet

This proposal must be received by close of business on Thursday, April 14, 1994 at:
CEBAF
User Liaison Office, Mail Stop 12 B
12000 Jefferson Avenue
Newport News, VA 23606

Proposal Title

Study of the Δ(1232) Using Double Polarization Asymmetries

Contact Person

Name: PAUL STOLER
Institution: Rensselaer Polytechnic Institute
Address: Physics Dept.
Address: R P I
City, State ZIP/Country: Troy, NY, 12180
Phone: (518) 276 - 8388 **FAX:** (518) 276 - 6680
E-Mail → Internet: STOLERP@RPIMEP.PHYS.RPI.EDU

Experimental Hall: B
Total Days Requested for Approval: Beam time already approved for Exp. 91-23. Additional 300 hrs conditional see text
Minimum and Maximum Beam Energies (GeV): 4.0
Minimum and Maximum Beam Currents (μAmps): see exp 91-23

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Receipt Date: 4/13/94 PR 94-003
By:

Proposal to PAC 8

Study of the Δ(1232) Using Double Polarization Asymmetries

A Hall B CLAS N* Collaboration Experiment

Spokespersons:

P. Stoler, RPI (contactperson)
V. Burkert, Z. Li, CEBAF
R. Minehart, U. Va

The members of the Hall B CLAS N* collaboration are: G.Adams[3], M. Anghinolfi[8], K. Beard[10], N. Bianchi[7], G.P. Capitani[7], V.Burkert[1], R. Chasteler[6], C.Carlson[4], A. Coleman[4], P. Corsiviero[8], D. Crabb[2], D.Day[2], E. De Sanctis[7], S.Dytman[11], L.Dennis[9], D.Doughty[5], P. Dragovich[9], H.Funsten[4], M.Gai[15], G. Gervino[8], K.Giovanetti[12], D. Heddle[5], P. Levi Sandri[7], Zh. Li [5], J. Lieb[14], M. Manley[13], R. Marshall[2], L. Mazzaschi[8], J. McCarthy[2], B.Mecking[1], M.Mestayer[1], R.Minehart[2], V. Mokeev[8], M. Muccifora[7], N.Mukhopadyay[3], B.Niczyporuk[1], D. Pocanic[2], O.Rondon-Aramayo[2], J. Napolitano[3], E. Poli[7], G. Rico[8], M. Ripani[8], A.R. Reolon[7], P. Rossi[7], M. Sanzone[8], R.Sealock[2], E.Smith[1], L.C. Smith[2], P.Stoler[3], M. Taiuti[8], D.R. Tilley[6], T. Tung[4], S.Thornton[2], H.Weber[2], H. Weller[6], B. Wojtsekhowski[1], A.Yegneswaren[1], A. Zucchiatti[8]

[1]*CEBAF*, [2]*Univ. of Virginia*, [3]*RPI*, [4]*William&Mary*, [5]*Christopher Newport*, [6]*Duke*, [7]*INFN – Frascati*, [8]*INFN – Genova*, [9]*Florida State*, [10]*Hampton*, [11]*Univ.of Pittsburgh*, [12]*JamesMadison*, [13]*Kent State*, [14]*George Mason*, [15]*Univ. of Conn.*

Physics motivation

CEBAF PROPOSAL COVER SHEET

This Proposal must be mailed to:

CEBAF
Scientific Director's Office
12000 Jefferson Avenue
Newport News, VA 23606

and received on or before 1 October 1991.

A. TITLE: Measurement of Polarized Structure Functions in Inelastic Electron Proton Scattering using the CEBAF Large Acceptance Spectrometer

B. CONTACT PERSON: Volker Burkert

ADDRESS, PHONE, AND ELECTRONIC MAIL ADDRESS:

CEBAF
Newport News, VA
BURKERT @ CEBAFVAX
804-249-7540

C. IS THIS PROPOSAL BASED ON A PREVIOUSLY SUBMITTED PROPOSAL OR LETTER OF INTENT?

[ ] YES [x] NO

IF YES, TITLE OF PREVIOUSLY SUBMITTED PROPOSAL OR LETTER OF INTENT:

****

(CEBAF USE ONLY)

Receipt Date 1 OCT 91
Log Number Assigned PR 91-023
By L. Smith

CEBAF Program Advisory Committee Six (PAC6) Proposal Cover Sheet

This proposal must be received by close of business on April 5, 1993 at:

CEBAF
User Liaison Office
12000 Jefferson Avenue
Newport News, VA 23606

Proposal Title

Measurement of Single Pion Electroproduction from the Proton with Polarized Beam and Polarized Target Using CLAS

Contact Person

Name: Dr. Henry Weller
Institution: Duke University and Triangle Universities Nuclear Laboratory
Address: Science Drive; Box 90308
Address:
City, State ZIP/Country: Durham, NC 27708-0308
Phone: 919/660-2633 **FAX:** 919/660-2525
E-Mail → BITnet: **Internet:** WELLER@TUNL.TUNL.DUKE.EDU

If this proposal is based on a previously submitted proposal or letter-of-intent, give the number, title and date:

CEBAF Use Only

Receipt Date: 4/5/93 Log Number Assigned: PR 93-036

By: go

Physics motivation

Abstract: We propose to use polarized beam and target to measure double polarization asymmetries for the $\Delta(1232)$ resonance over a Q^2 range from about 0.5 to 4 GeV^2/c^2. We will measure the kinematically complete reactions $p(e,e'p)\pi^0$ and $p(e,e'\pi^+)n$ over the full $\Delta(1232)$ mass range, and obtain nearly a full 4π angular distribution for several kinematic regions in Q^2.

This experiment will provide us with unique information about the $N \rightarrow \Delta$ transition amplitudes, M_{1+}, E_{1+} and S_{1+}, and their interferences, which is complementary to measurements of cross sections using unpolarized beam or target. Also, the measurement of asymmetries will give rize to much smaller systematic errors which occur in absolute cross section measurements.

The, experiment is especially well suited to Hall B since the maximum acceptable luminosity of the polarized $^{15}NH_3$ target matches that of the CLAS spectrometer. In this experiment it will only be necessary to detect the scattered electrons and one of the emitted hadrons to achieve full kinematic reconstruction. Most of the experiment, especially the low Q^2 part, will utilize beam time already approved in conjunction with experiment E-91-23. In addition, we request an additional 300 hours of beam at 4 GeV to obtain increased statistical accuracy at higher Q^2, contingent upon successful utilization of the already approved beam time. Even though at these cm energies only single meson production is kinematically allowed missing mass reconstruction will enable us to eliminate most of the backgrounds associated with the polarized target.

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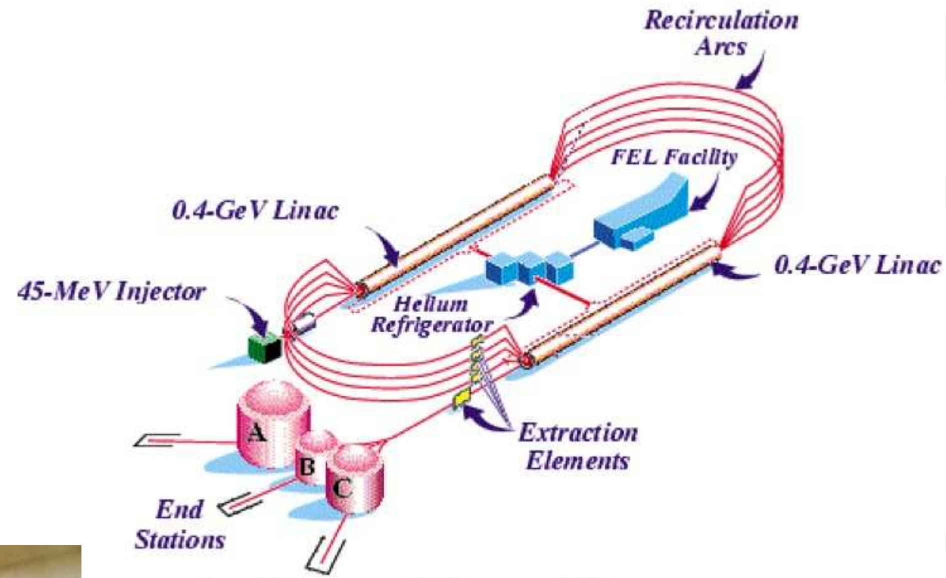
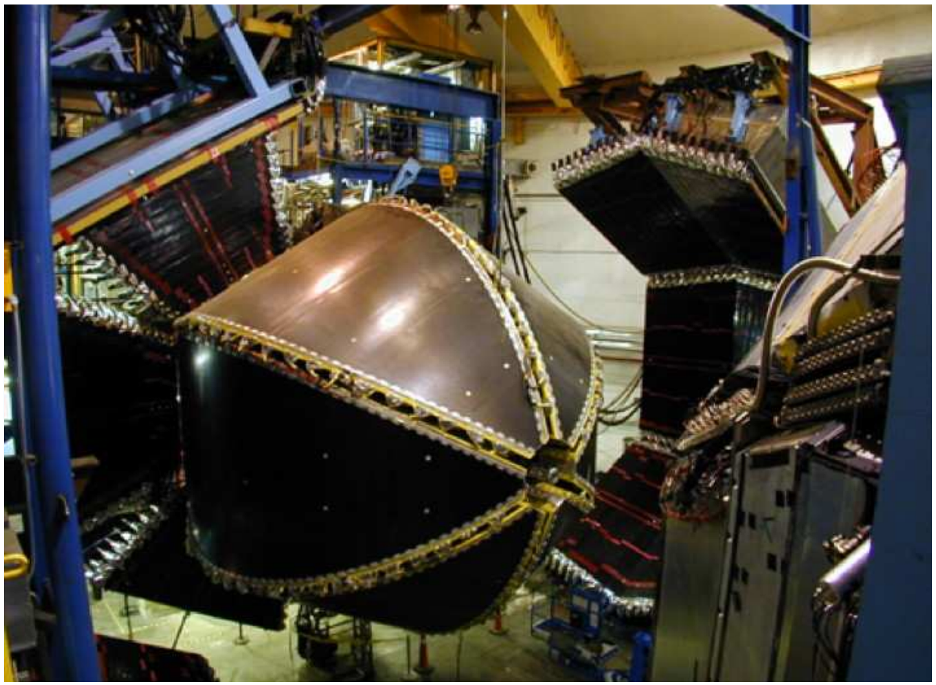
The experiment

CEBAF and Hall B

- E_{max} = 6 GeV
- I_{max}=200μA
- CLAS detector





EG1a experiment

- September to December 1998
- E=2.565 GeV
- I = 2 nA
- Beam pol 70%

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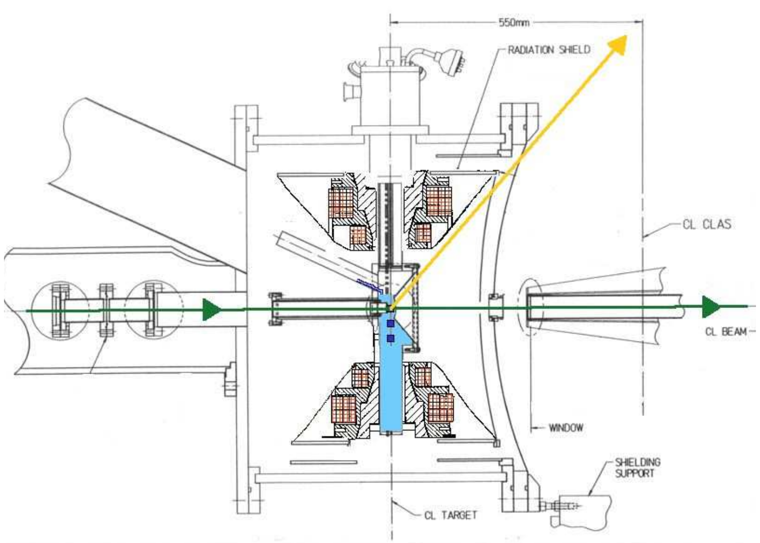
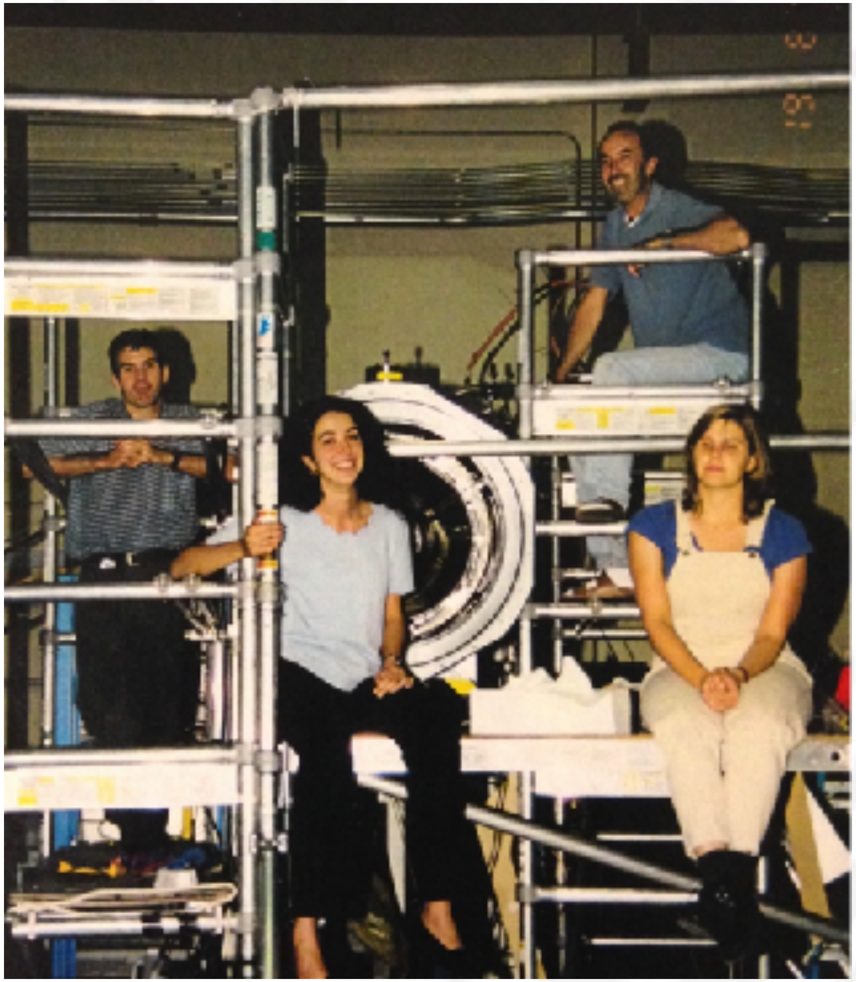
The polarized target

- NH_3 target
- P_t=+39%, -55%
- DNP polarization
- ^{12}C and empty targets





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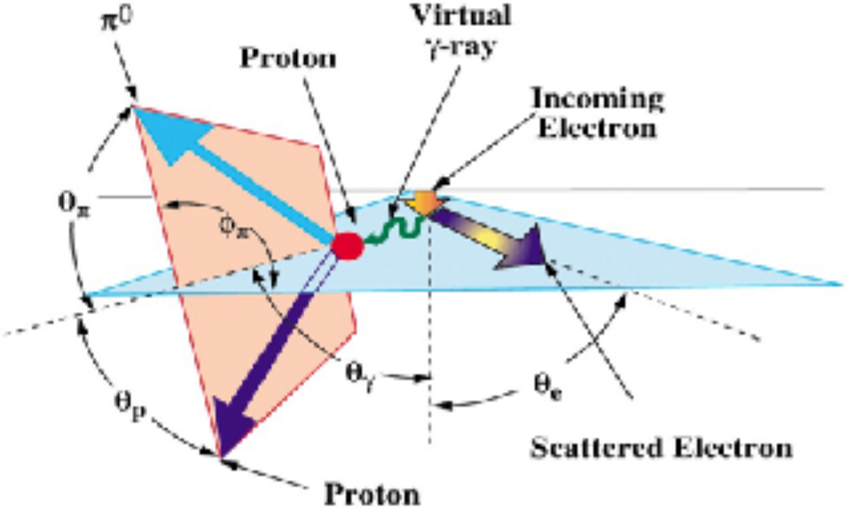
The analysis $\vec{e}\vec{p} \rightarrow ep\pi^0$

$$\sigma(W, Q^2, \theta_\pi, \phi_\pi) = (\sigma_0 + P_e\sigma_e + P_t\sigma_t + P_eP_t\sigma_{et})$$



$$A_t = \frac{\sigma_t}{\sigma_0} = \frac{1}{f}\frac{(N_{\uparrow\uparrow} + N_{\downarrow\uparrow}) - (N_{\uparrow\downarrow} + N_{\downarrow\downarrow})}{(N_{\uparrow\uparrow} + N_{\downarrow\uparrow}) + (N_{\uparrow\downarrow} + N_{\downarrow\downarrow})}$$

$$A_{et} = -\frac{\sigma_{et}}{\sigma_0} = -\frac{1}{f}\frac{(N_{\uparrow\uparrow} - N_{\downarrow\uparrow}) - (N_{\uparrow\downarrow} - N_{\downarrow\downarrow})}{(N_{\uparrow\uparrow} + N_{\downarrow\uparrow}) + (N_{\uparrow\downarrow} + N_{\downarrow\downarrow})}$$

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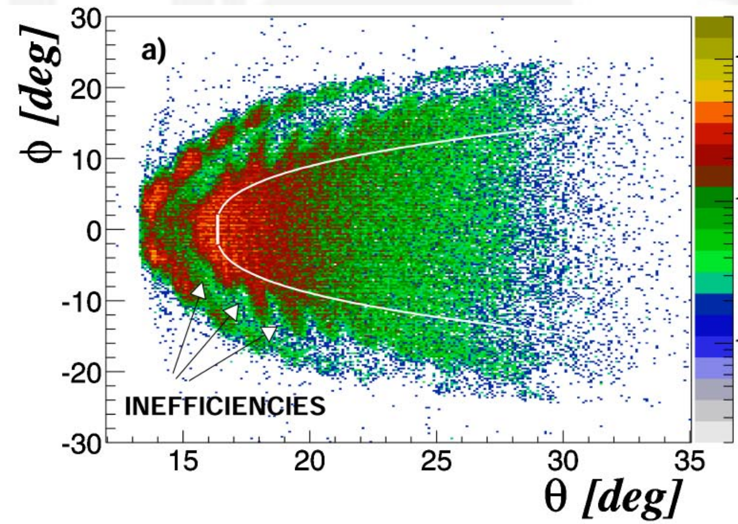
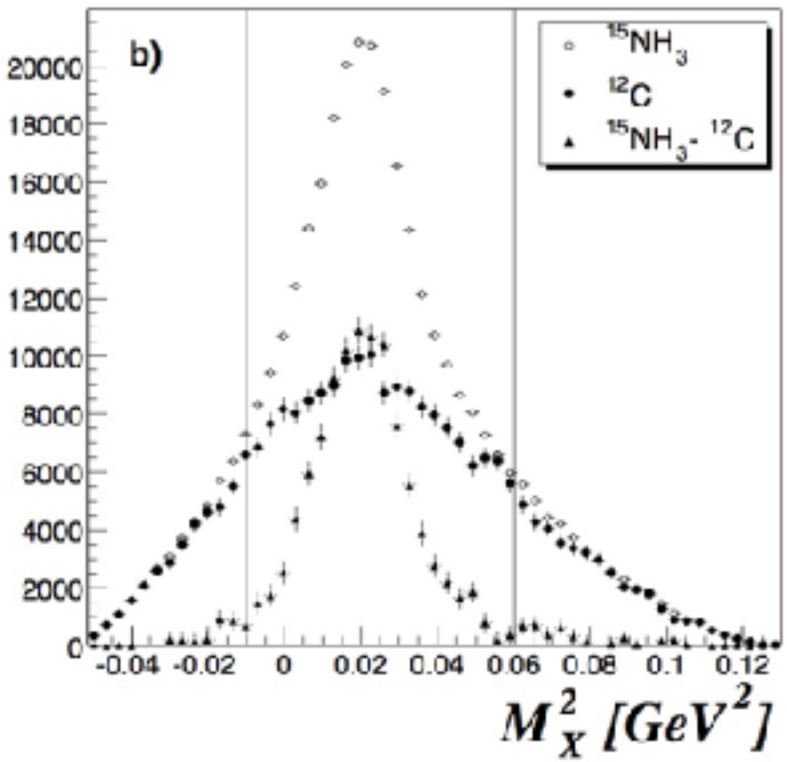
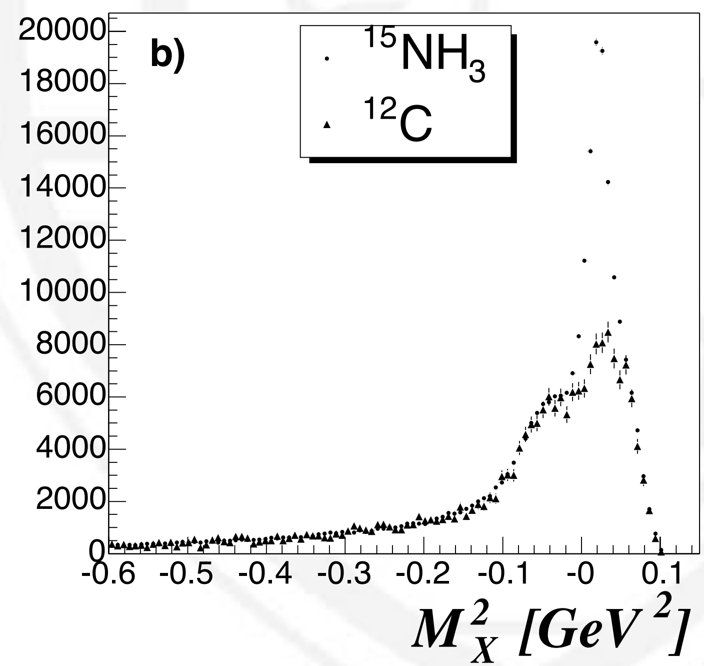
The analysis $\vec{e}\vec{p} \rightarrow ep\pi^0$

Well known things now, not so well known back then:

- Carbon normalization
- CC inefficiencies
- P_bP_t extraction
- Acceptance







Physics Analysis Workstation

STUDY OF THE Δ(1232) USING DOUBLE POLARIZATION ASYMMETRIES

By

Angela Biselli

A Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Physics

Approved by the
Examining Committee:

Paul Stoler, Thesis Adviser

Gary Adams, Member

Volker Burkert, Member

James Napolitano, Member

Wayne Roberge, Member

Mauro Taiuti, Member

Rensselaer Polytechnic Institute
Troy, New York

March 2002
(For Graduation May 2002)

PHYSICAL REVIEW C **68**, 035202 (2003)

$ep \to ep\pi^0$ reaction studied in the Δ(1232) mass region using polarization asymmetries

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(CLAS Collaboration)

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0556-2813/2003/68(3)/035202(14)/$20.00 **68** 035202-1

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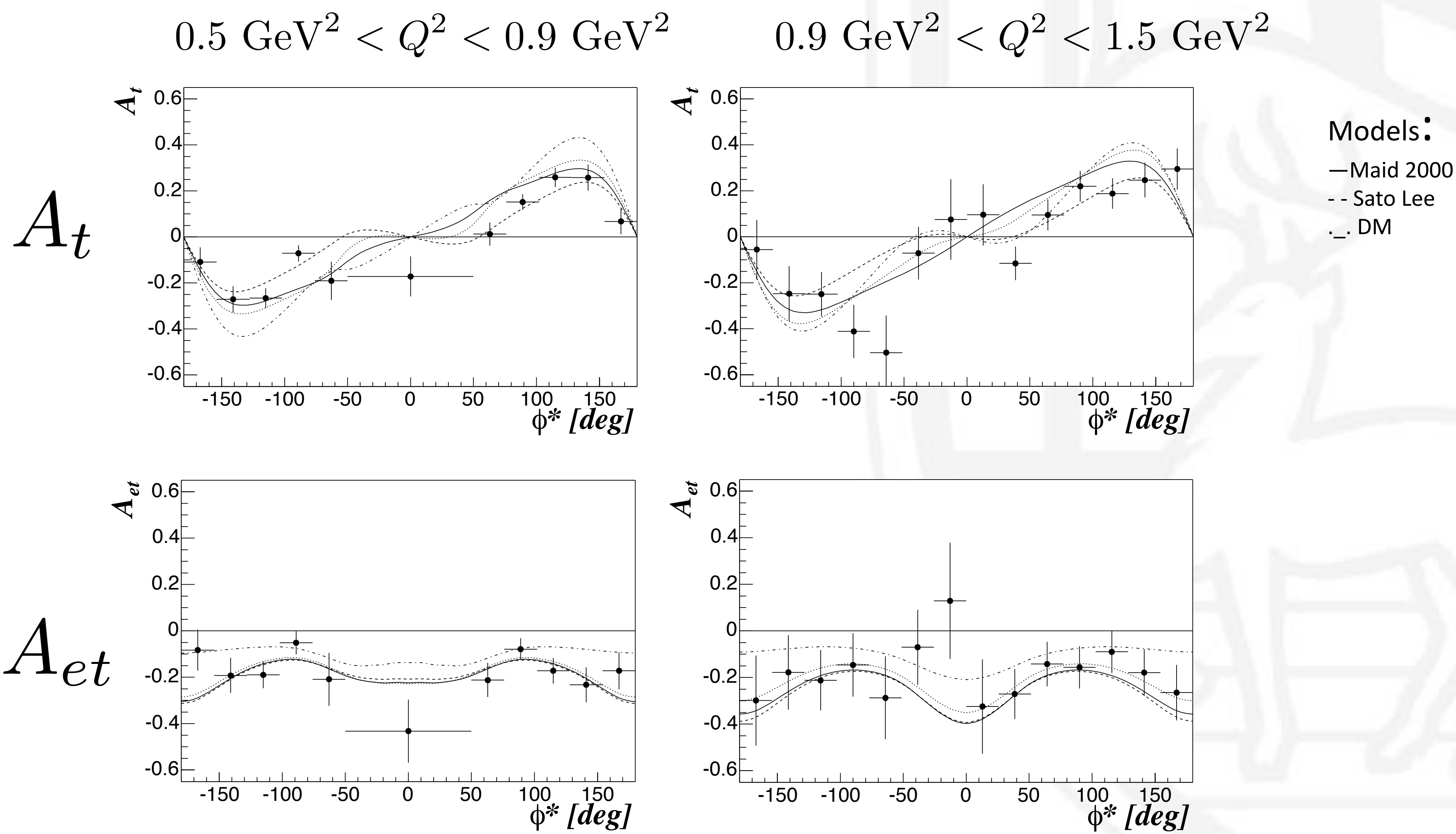
The results



Asymmetries integrated over cos(θ*)

A_{et} characterized by M_{1+}^2 well know from x-section

A_t sensitivity to background multipoles

What is the next step? (Paul's favorite question)

The eg1b experiment

- Same setup
- E_{beam}=1.6, 2.5, 4.2, 5.7 GeV
- Both in-bending and out-bending
- Both NH_3, ND_3
- Beam polarization 70%
- NH_3 polarization ~70%
- Run in 2000

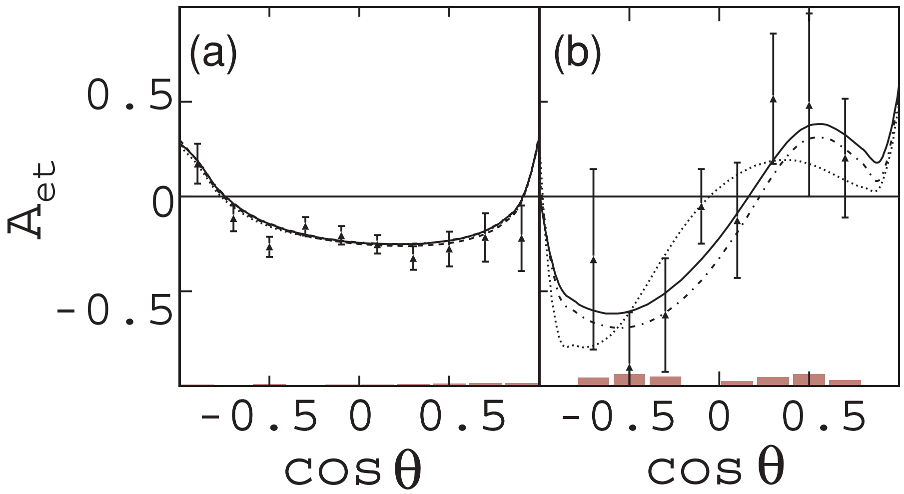
$$\vec{e}\vec{p} \rightarrow ep\pi^0$$

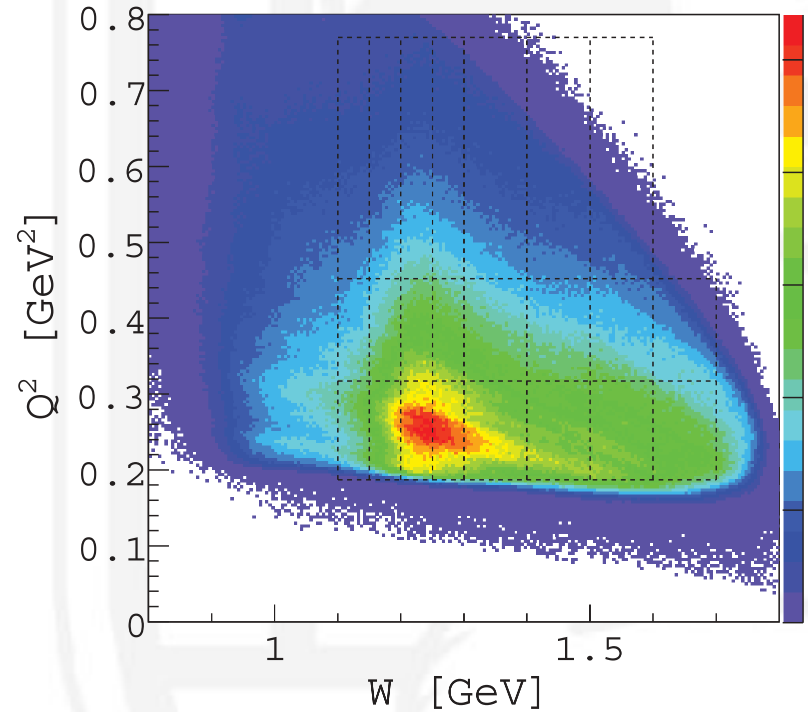
- E_{beam}=1.6 GeV in-bending
- Both NH_3
- three Q^2 bins
- seven W bins
  - 4 in the delta region
  - 3 from 1.3 to 1.7 GeV

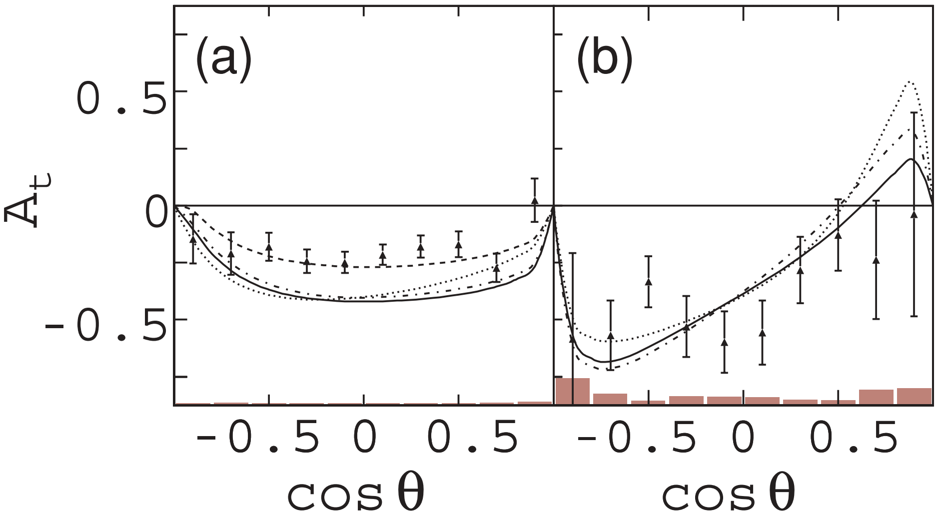
First measurement of the target and double spin asymmetries in the region above the Δ(1232) resonance

Biselli et al. Phys. Rev. C 78, 045204

The results







- Asymmetries extracted in 3x8x10x15 bins.
- ~2400 non-zero data points for each asymmetry

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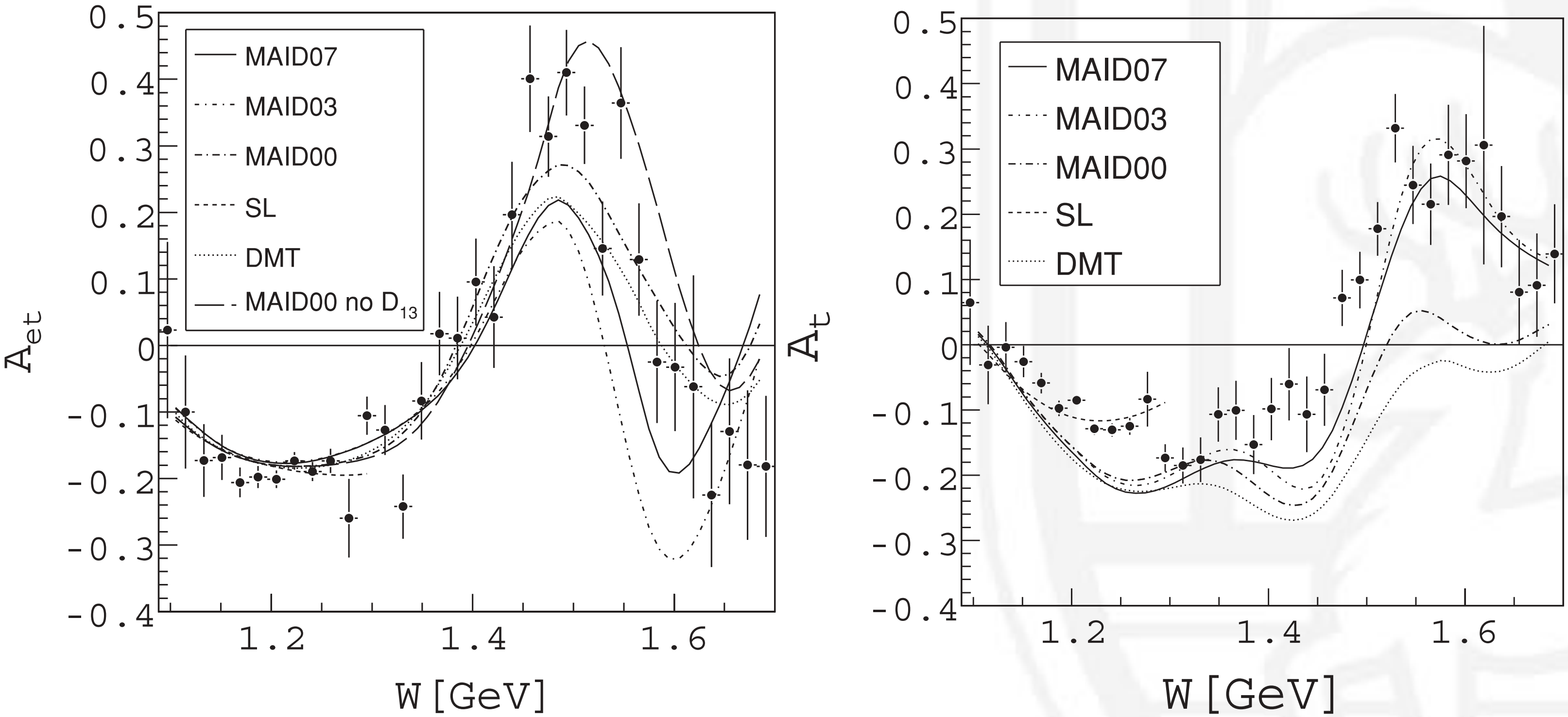
The results A_{et} and A_t vs W



Asymmetries integrated over cos(θ) and non-zero acceptance region in 60<ϕ<156 deg

Δ(1232) region:

- A_{et} agreement with all models -> M_1^+ dominance, well know from x-sections
- A_t agreement with Sato-Lee model, background sensitivity

Higher resonance region:

- A_{et} sensitivity to D_{13}
- A_t agreement with MAID

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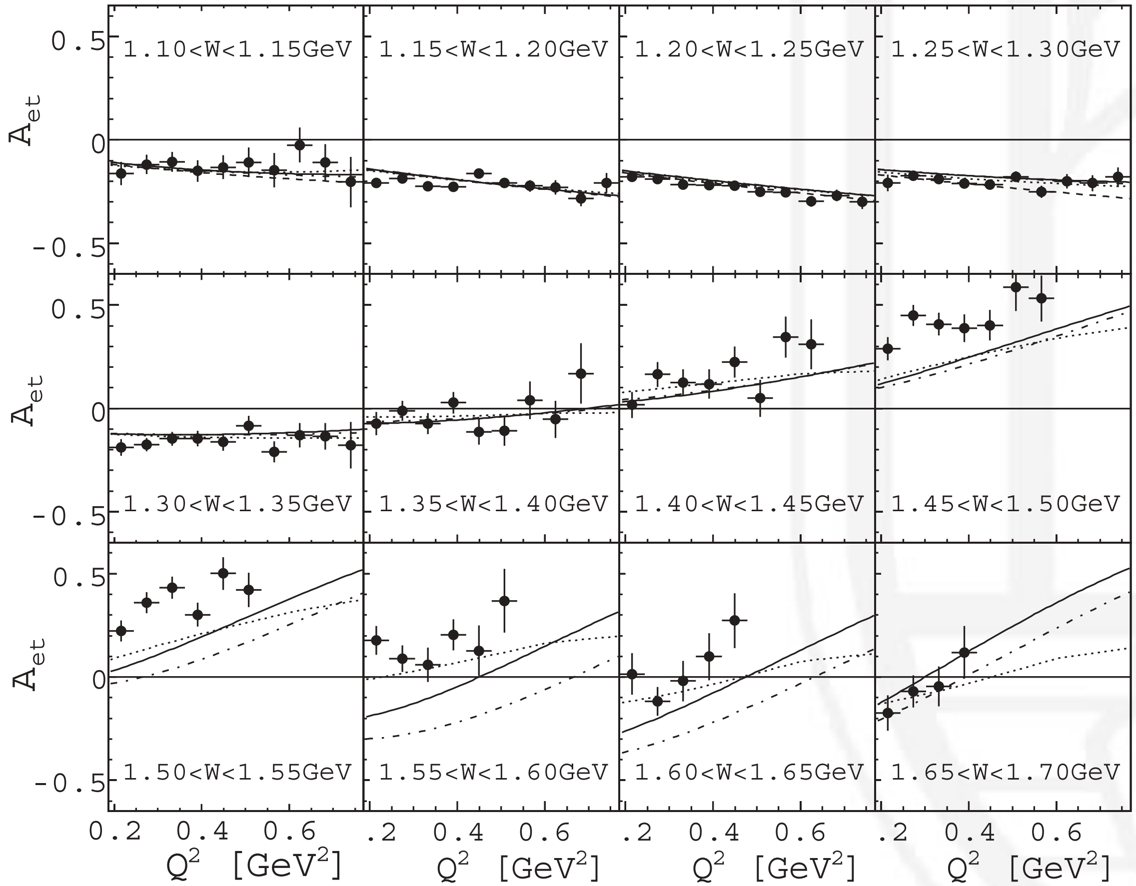
The results A_{et} vs Q^2



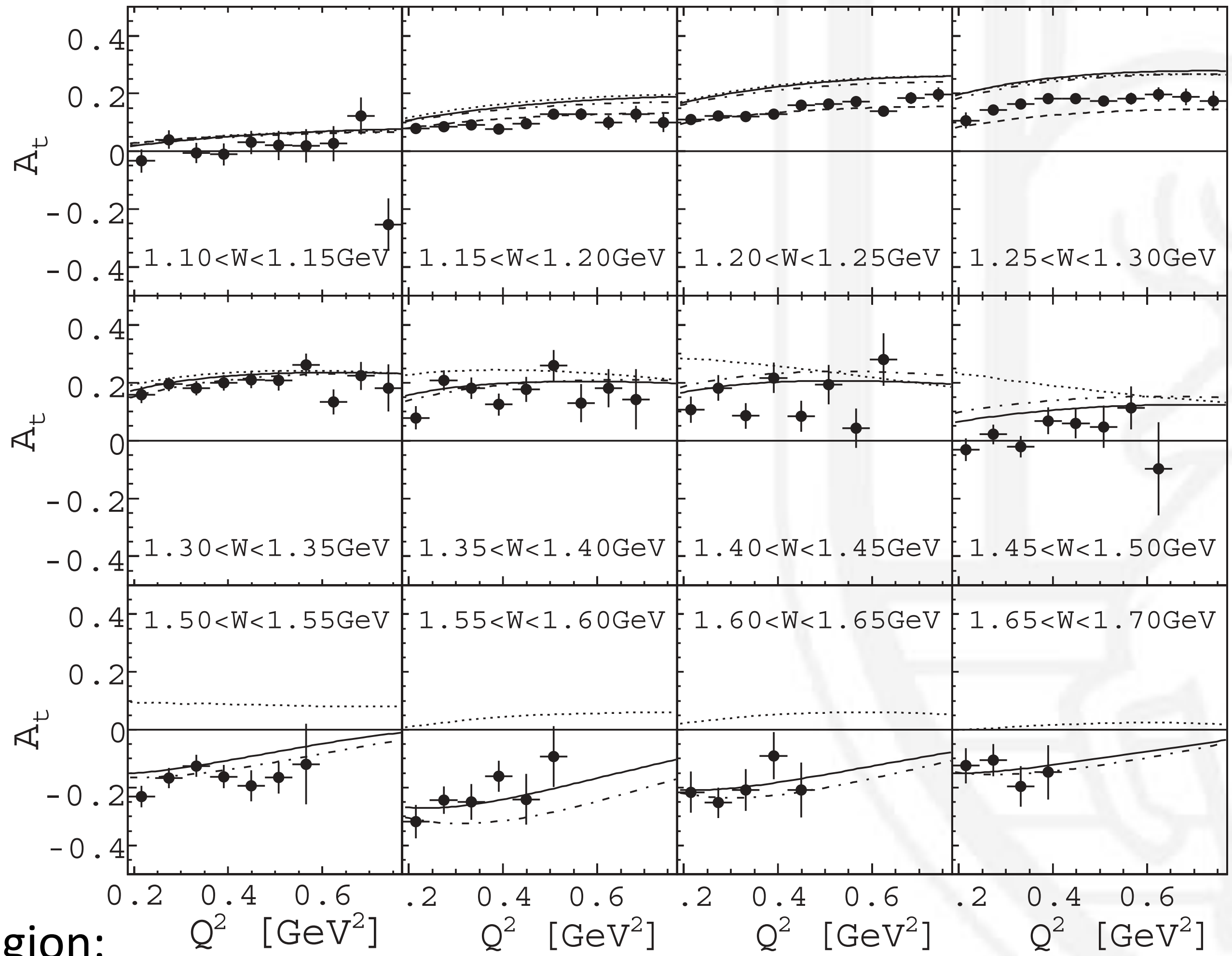
Δ(1232) region:

- linear, negative slope , well described by all models

Higher resonance region:

- positive slope, rapidly increasing with Q^2, models underestimate the magnitude
- Sensitivity to the relative strength of the $A_{1/2}$ $A_{3/2}$ of the D_{13}(1520)

The results A_t vs Q^2



Δ(1232) region:

- described well only by SL

Higher resonance region:

- described well by MAID

Electro-excitation of nucleon resonances from CLAS data on single pion electro-production

Aznauryan, et al. Phys. Rev. C 78, 045204

- Comprehensive analysis of CLAS data of pion electro-production off protons.
- Different observables: cross sections, beam asymmetries, target and double spin asymmetry
- Two approaches:
  - Fixed t dispersion relations (DR)
  - electro coupling amplitudes (UIM)

Observable	Q^2 (GeV^2)	W (GeV)	Number of data points (N)	χ^2/N DR	χ^2/N UIM	Ref.
$\frac{d\sigma}{d\Omega}(\pi^+)$	0.3	1.1-1.55	2364	2.06	1.93	[4]
$A_t(\pi^0)$	0.252	1.125-1.55	594	1.36	1.48	[8]
$A_{et}(\pi^0)$	0.252	1.125-1.55	598	1.19	1.23	[8]
$\frac{d\sigma}{d\Omega}(\pi^0)$	0.4	1.1-1.68	3530	1.23	1.24	[1]
$\frac{d\sigma}{d\Omega}(\pi^+)$	0.4	1.1-1.55	2308	1.92	1.64	[4]
$A_{LT'}(\pi^0)$	0.4	1.1-1.66	956	1.24	1.18	[2]
$A_{LT'}(\pi^+)$	0.4	1.1-1.66	918	1.28	1.19	[3]
$A_t(\pi^0)$	0.385	1.125-1.55	696	1.40	1.61	[8]
$A_{et}(\pi^0)$	0.385	1.125-1.55	692	1.22	1.25	[8]
$\frac{d\sigma}{d\Omega}(\pi^0)$	0.525	1.1-1.66	3377	1.33	1.35	[1]
$\frac{d\sigma}{d\Omega}(\pi^+)$	0.5	1.1-1.51	2158	1.51	1.48	[4]
$\frac{d\sigma}{d\Omega}(\pi^0)$	0.65	1.1-1.68	6149	1.09	1.14	[1]
$\frac{d\sigma}{d\Omega}(\pi^+)$	0.6	1.1-1.41	1484	1.21	1.24	[4]
$\frac{d\sigma}{d\Omega}(\pi^+)$	$\simeq 0.6$	1.4-1.76	477	1.72	1.74	[43]
$A_{LT'}(\pi^0)$	0.65	1.1-1.66	805	1.09	1.13	[2]
$A_{LT'}(\pi^+)$	0.65	1.1-1.66	812	1.09	1.04	[3]
$A_t(\pi^0)$	0.611	1.125-1.55	930	1.38	1.40	[8]
$A_{et}(\pi^0)$	0.611	1.125-1.55	923	1.26	1.28	[8]

Observable	Q^2 (GeV^2)	W (GeV)	Number of data points (N)	χ^2/N DR	χ^2/N UIM
$\frac{d\sigma}{d\Omega}(\pi^+)$	1.72	1.11-1.69	3530	2.3	2.5
	2.05	1.11-1.69	5123	2.3	2.2
	2.44	1.11-1.69	5452	2.0	2.0
	2.91	1.11-1.69	5484	1.9	2.1
	3.48	1.11-1.69	5482	1.3	1.4
	4.16	1.11-1.69	5778	1.1	1.1
$A_{LT'}(\pi^+)$	1.72	1.12-1.68	699	2.9	3.0
	2.05	1.12-1.68	721	3.0	2.9
	2.44	1.12-1.68	725	3.0	3.0
	2.91	1.12-1.68	767	2.7	2.7
	3.48	1.12-1.68	623	2.4	2.3

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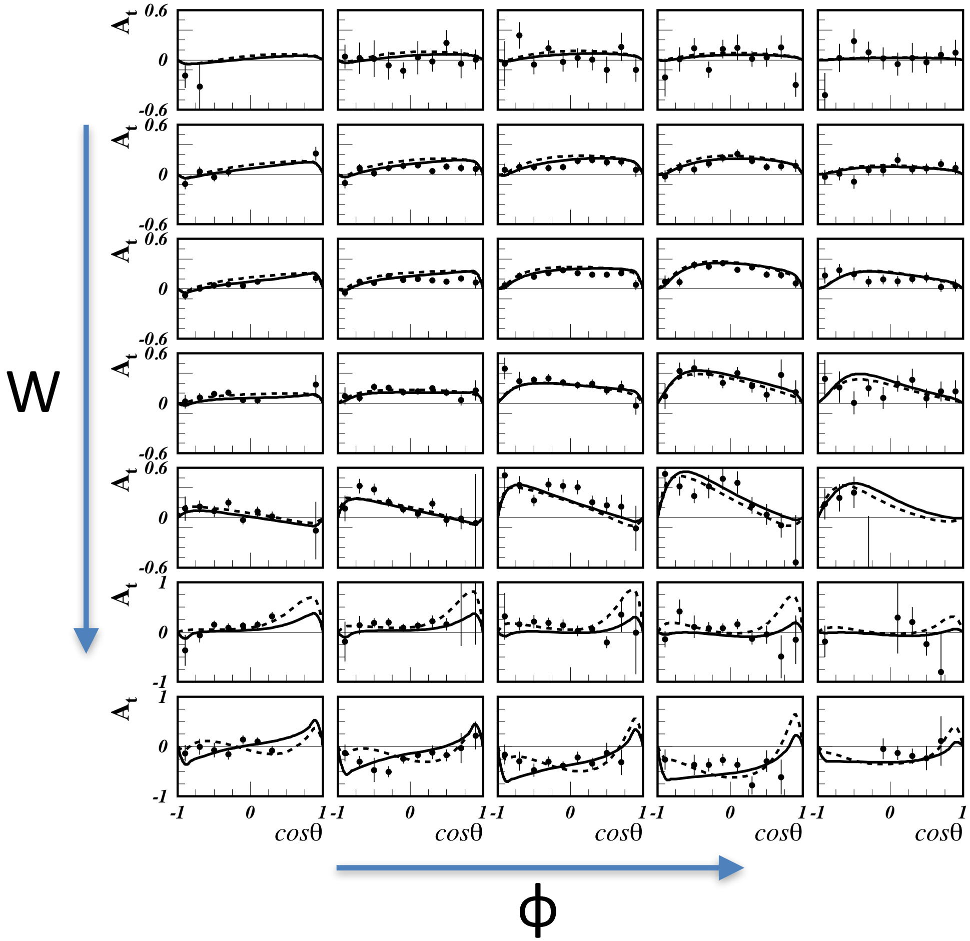
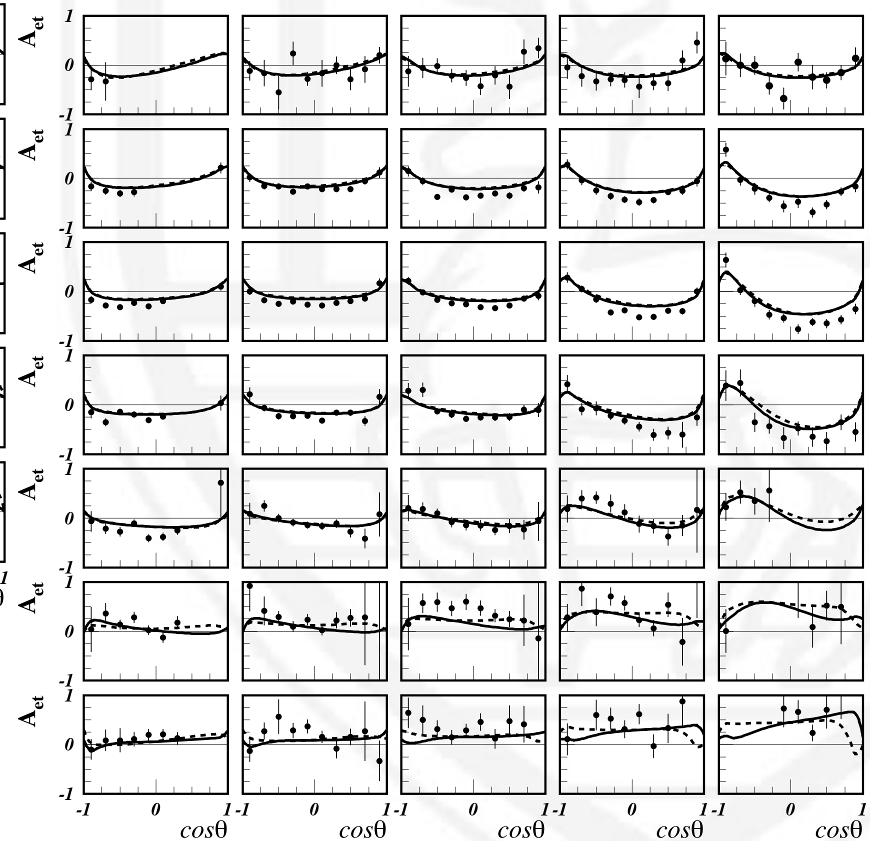
[1] K. Joo et al., CLAS Collaboration, Phys. Rev. Lett. 88, 122001 (2002).
[2] K. Joo et al., CLAS Collaboration, Phys. Rev. C 68, 032201 (2003).
[3] K. Joo et al., CLAS Collaboration, Phys. Rev. C 70, 042201 (2004).
[4] H. Egiyan et al., CLAS Collaboration, Phys. Rev. C 73, 025204 (2006).
[8] A. Biselli et al., CLAS Collaboration, Phys. Rev. C 78, 045204 (2008).

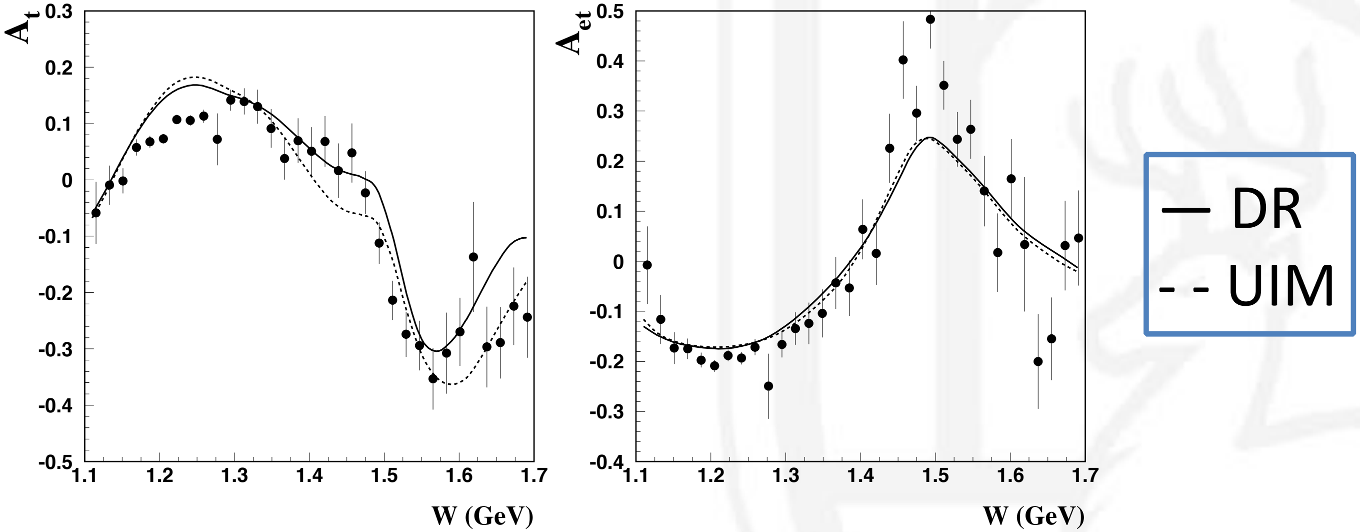
Fits results for At an Aet





At and Aet vs cos(θ) for Q^2= 0.385 GeV^2

Fits results for At an Aet vs W



- Smaller magnitude of $S_{1/2}$ for the Roper
- Larger $A_{1/2}$ and smaller $|S_{1/2}|$ amplitudes for γ p → N(1535)S_{11} transition
- Minor impact on the $\gamma * p$ → Δ(1232)P_{33} and N(1520)D_{13} amplitudes

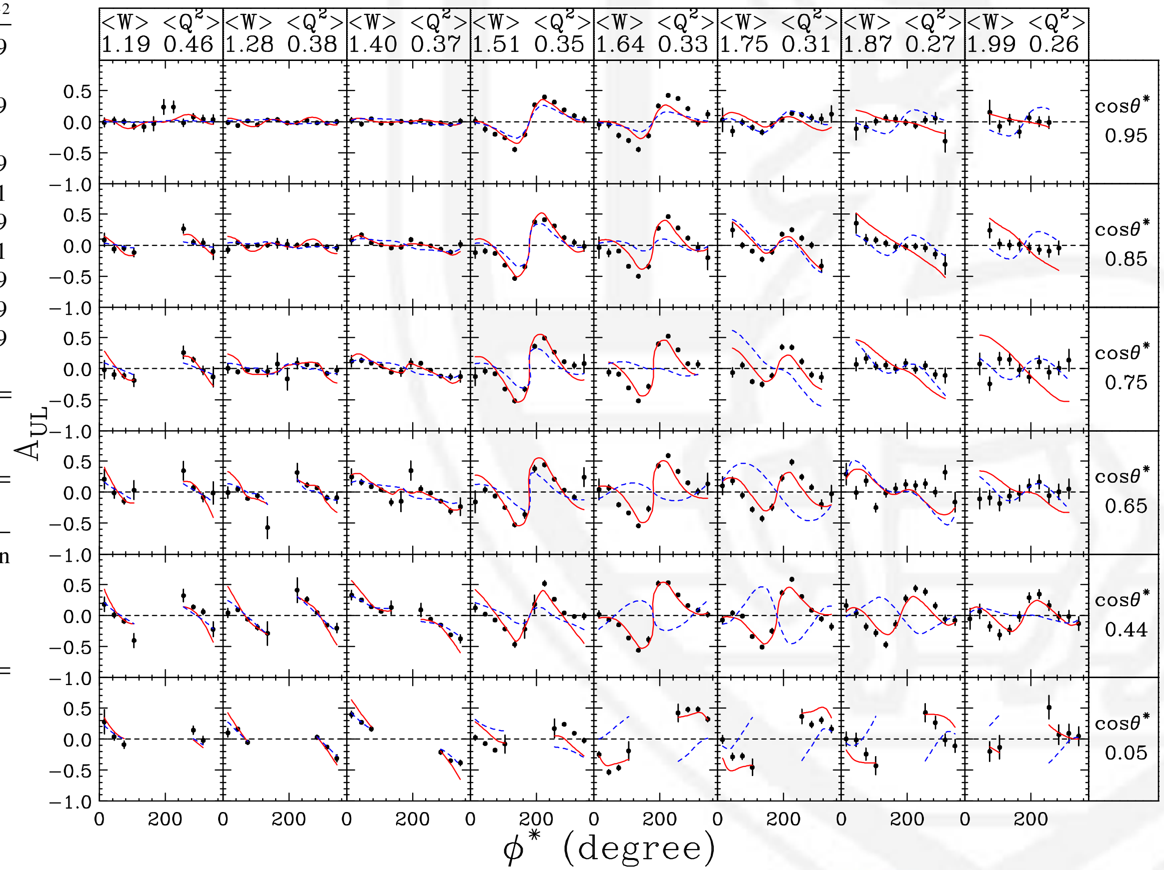
More eg1b?

Target and beam-target spin asymmetries in exclusive π^+ and π^- electroproduction with 1.6- to 5.7-GeV electrons

Bosted. etc al Phys. Rev C **94**, 055201 (2016)

Run period	Beam energy	I torus	$P_B P_T$(p)	$P_B P_T$(d)	$R^p_{A>2}$	$R^d_{A>2}$
Part 1p6i	1.603 GeV	1500 A	0.55	0.21	0.86	0.99
(Part 1p6o)	1.603 GeV	−1500 A	–	–	–	–
Part 1p7o	1.721 GeV	−1500 A	0.58	0.21	0.81	0.99
Part 2p2i	2.285 GeV	1500 A	0.50	–	0.86	–
Part 2p5i	2.559 GeV	1500 A	–	0.21	–	0.99
Part 2p5o	2.559 GeV	−1500 A	0.61	0.25	0.86	1.01
Part 4p2i	4.236 GeV	2250 A	0.54	0.18	0.85	0.99
Part 4p2o	4.236 GeV	−2250 A	0.55	0.18	0.88	1.01
Part 5p6i	5.612 GeV	2250 A	0.50	0.20	0.815	0.99
Part 5p72i	5.722 GeV	2250 A	0.50	0.20	0.815	0.99
Part 5p72o	5.722 GeV	−2250 A	0.50	0.19	0.83	0.99
(Part 5p74o)	5.740 GeV	−2250 A	0.50	0.19	–	–

Topology	Final state particles
$ep \to e\pi^+ n$	Electron, π^+, neutron
$ed \to e\pi^- p(p)$	Electron, π^-, proton
$ep \to e\pi^+(n)$	Electron, π^+
$ed \to e\pi^-(pp)$	Electron, π^-



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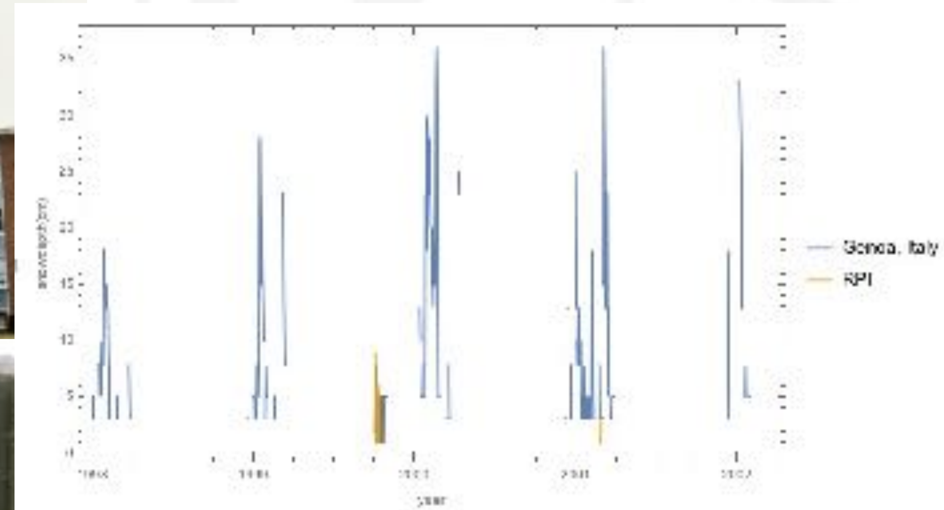

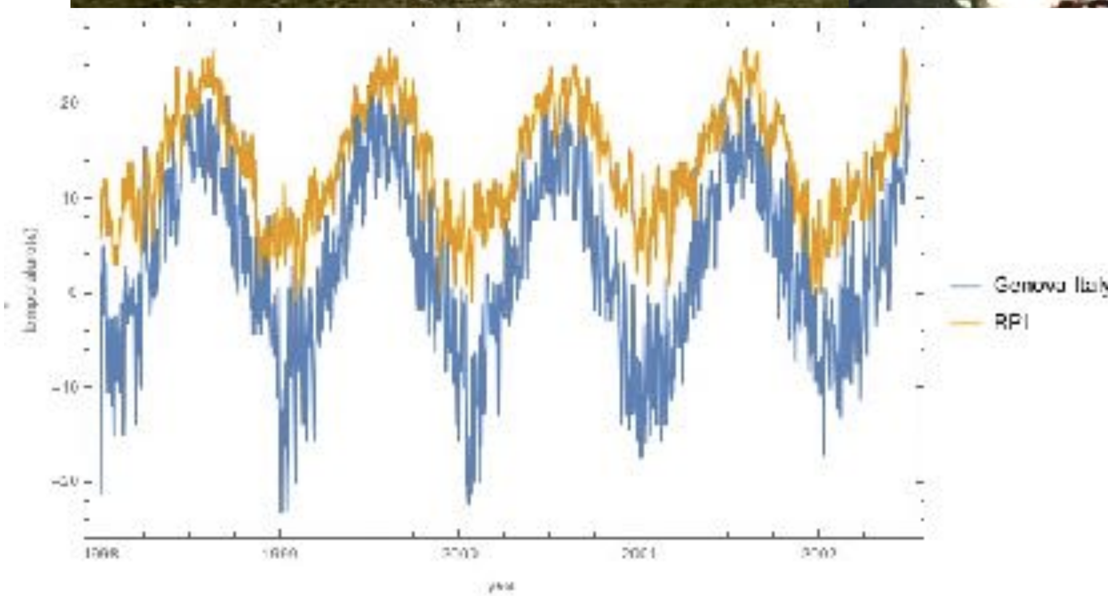

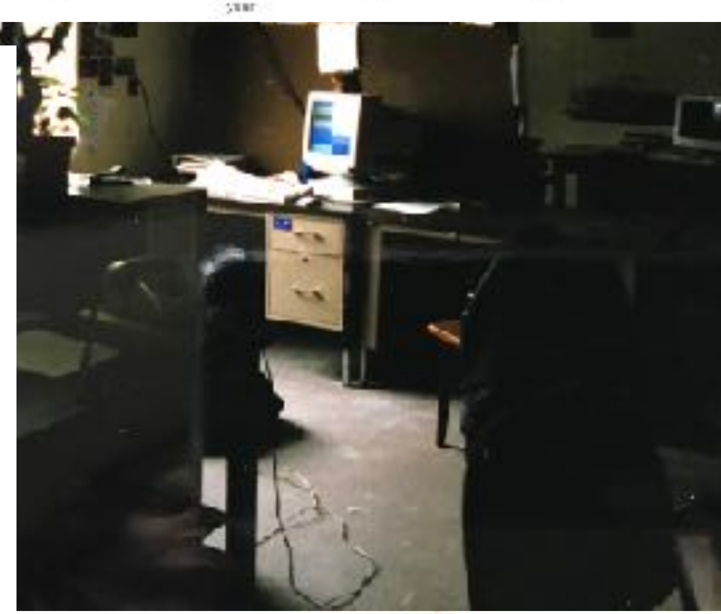

Back to Contents

AT RENSSELAER

Class of 2002

Despite the Snow, Commencement Goes On

A snowstorm on May 18?

That's what Rensselaer staff, faculty, and soon-to-be graduates awoke to on Commencement morning. The decked-out and chair-covered Harkness Field, the planned site for Rensselaer's 196th Commencement ceremonies, was covered with a thin blanket of snow.

Because of the unexpected storm, the ceremony was quickly moved indoors to the Houston Field House. Once the ceremony began, Rensselaer conferred 861 bachelor's, 221 master's, and 47 doctoral degrees to the members of the Class of 2002.

Rensselaer also conferred honorary doctoral degrees on civilian space traveler Dennis Tito '64, moviemaker Bobby Farrelly '81, genomics scientist Claire Fraser '77, and Brown University President Ruth Simmons.

Class of 2002 graduates braved the storm to join (center) Institute Board Chairman Sam Heffner '56, President Shirley Ann Jackson, and Architecture Dean Alan Balfour at Harkness Field Commencement morning. Photo by Thomas Griffin.

RPI students and postdocs

Advisor and friend

Thank you Paul.